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Understanding the Gold King Mine Spill

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On Wednesday August 5, 2015, during an EPA mine site investigation of the Gold King Mine near Silverton, CO, heavy equipment disturbed loose material around a soil "plug" at the mine entrance. Apparently, acid mine drainage had built up behind the plug, which unexpectedly gave way due to the weight of the water pressure in the tunnel, and a torrent of water gushed out of the tunnel (Figure 1). This accident resulted in the release of approximately 3 million gallons of contaminated water into Cement Creek which flows into the Animas River. The water contains a number of heavy metals such as lead and arsenic. The spill has affected waterways throughout the Colorado River Basin, which impacts 6 states and 12 tribes. This area in Colorado has a history of mining since the 1800's and there is a history of toxic leaks going into the river (Church et al., 2007). However, this may be one of the largest toxic spills in this region.

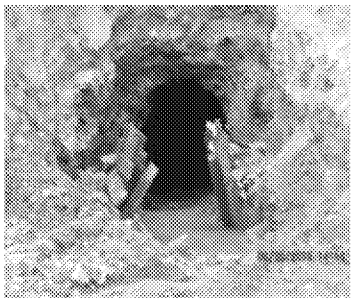

Figure 1. The mining tunnel from which the toxic spill occurred (EPA, 2015).

Why is the water yellow?

Many abandoned mines have deep tunnels below the water table that were created to mine ore. During mining, water is pumped out of the tunnels, but after the mine is closed, the water table can rise back up, filling the empty tunnels with water. When the ore in the tunnels is exposed to water and air, acid is generated and metals from the rock seep into the water. This creates a thick, metal-filled mixture called "acid mine drainage." Acid mine drainage is usually a rusty red to orange color due to the presence of iron. When a spill occurs into a waterway, and the acid mine drainage is mixed with freshwater, it becomes less acidic, which changes the chemistry of the metals. The iron from the red-orange acid mine drainage settles into the water, turning it yellow. Old-time miners referred to this as "yellow boy." The color of the water, which indicates iron content, does not indicate the toxicity of the water. Federal notices concerning water use should be adhered to.

Table 1. Weight of metals, highest to lowest, released in 3,043,067 gallons of toxic waste from Gold King Mine estimated by the University of Arizona from EPA measurements at the Cement Creek 14th St. Bridge on Aug. 5, 2015 16:00 (EPA, 2015).

Metal	Pounds	Metal	Pounds	Metal	Pounds
Iron	248,582	**Copper**	919	**Cobalt**	10
Aluminum	23,657	**Sodium**	586	**Antimony**	8
Calcium	11,365	**Barium**	244	**Nickel**	7
Magnesium	6,984	**Arsenic**	206	**Mercury**	6
Potassium	5,307	**Vanadium**	137	**Cadmium**	4
Lead	4,481	**Molybdenum**	50	**Beryllium**	3
Manganese	1,953	**Silver**	28	**Selenium**	-
Zinc	1,101	**Chromium**	18	**Thallium**	-

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What is in the water and how big is the spill?

The contaminated water contained various metals with the highest being iron, aluminum, calcium, and magnesium as well as toxic metals including lead, arsenic, mercury and cadmium (Table 1). The volume of this toxic spill was 3,043,067 gallons, approximately 9.3 acre-feet, the amount in 250 swimming pools, or 9 football fields spread out one foot deep.

Who regulates these abandoned mines?

Prior to the 1970's, mining operations were not well-regulated and as a result, there is a legacy of abandoned mines. There are thousands of inactive or abandoned mines on federal, state, tribal, and private lands, especially throughout the western United States. In Arizona alone, there are approximately 24,183 abandoned mines (BLM, 2014). Some abandoned mines may pose little risk while others may pose potentially larger environmental impacts. Reclamation of abandoned mines to a pre-mining state of land is difficult, if not impossible. It is often a long, arduous and expensive process. For example, the United States Environmental Protection Agency (US EPA) Office of Inspector General identified 156 "mega" hard rock mining sites nationwide with the potential to cost $24 billion to clean up and maintain, which is over 12 times the annual US EPA budget for remediation of large hazardous waste sites (i.e., Superfund site) (Lovingood et al., 2004). These sites are subject to environmental regulations that were created in the early 1970's to regulate environmental contaminants released by industry, cities, and users in order to protect human and environmental health. EPA is the agency charged with overseeing abandoned mines and works to clean up and close such sites.

What is the history of the Gold King Mine?

The Gold King Mine is an abandoned mine located near Silverton, Colorado within the Animas Watershed at 11,300 feet elevation. This area has a 121-year history of mining from 1871 to 1991 of which 8.6 million short tons of mill tailings were discharged into the Animas River and its tributaries (Church et al., 2007). Mining increased due to World War II and Korean War government incentives and decreased after 1953 because of costs and metal prices. Gold King Mine continuously discharged acid mine drainage into Cement Creek and contributes significantly to the amounts of manganese, zinc, copper, and cadmium in Cement Creek (EPA, 2015). The last maintenance at this mine had been in 1995 when a mine portal collapsed.

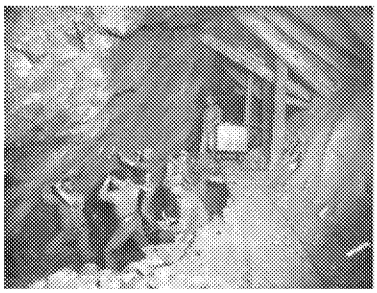

Figure 2. Gold King Mine 1899 (Church et al., 2007).

Who may be impacted by the spill?

The Gold King Mine spill occurred in the Colorado River Basin where the impacted waters flow through 6 U.S. states and into Mexico. The impacted water is used by or adjacent to 12 Native American tribes within this area (Figure 2, Table 2). The Southern Ute Indian Tribe, the Navajo Nation, the Ute Mountain Ute Indian Tribe, and the Jicarilla Apache Tribe are tribes whose waterways are nearest to the spill. Many local Navajo farmers use this water to irrigate their fields and water their livestock. Starting in Colorado, the first impacted water body is Cement Creek which flows south into the Animas River through Durango, CO, where residents rely on the Animas River for drinking water and recreational purposes. From there it flows into the San Juan River in New Mexico. At the confluence of these two rivers is the critical habitat for the Colorado Pike Minnow fish and the Razorback Sucker fish. The San Juan River flows west through Utah

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and flows into the Colorado River. From there it flows south to Arizona where the impacted water encounters its first dam, the Glen Canyon Dam at Lake Powell. From this point forward, there are 9 tribes who have water rights or adjacent lands to the Colorado River. The river then flows south towards Nevada at Lake Mead and Hoover Dam continuing south through several dams until it reaches Mexico after passing Imperial Dam. The major diversions are the Central Arizona Project, the Colorado River Aqueduct, and the All-American Canal. These diversions are for domestic use for major cities including: Las Vegas, NV; Phoenix, AZ; and Tucson, AZ and for agricultural use as far south as Yuma, AZ and Quechan Indian Tribe of the Fort Yuma Reservation.

Table 2: Tribes downstream of Gold King Mine

1	Southern Ute Indian Tribe
2	Navajo Nation
3	Ute Mountain Ute Indian Tribe
4	Jicarilla Apache Tribe
5	Northern Ute Tribe
6	Havasupai
7	Hualapai
8	Colorado River Indian Tribes
9	Fort Mojave Indian Tribe
10	Chemehuevi Indian Tribe
11	Cocopah Indian Community
12	Quechan Indian Tribe of Fort Yuma

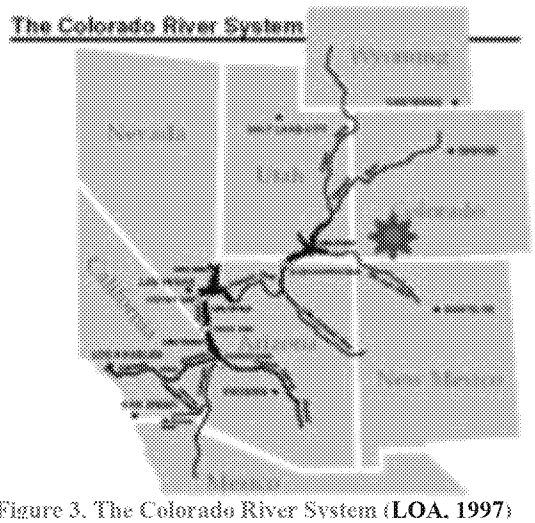

Figure 3. The Colorado River System (**LOA, 1997**)

What is being done to control the spill?

Within a day, EPA built settling ponds to divert the toxic flow away from the creek and used caustic soda to neutralize the acid mine drainage and flocculent to precipitate metals out of the water (EPA, 2015). As the contaminated water moved down the river from the spill site it also mixed with and became diluted in the local river waters. The Animas River is a fast flowing river with no dams so stopping the toxic waste or pumping the spill was not possible. Allowing the spill to become naturally diluted with the river flow was the only alternative. Thus, as the contaminated water moves from the site, it becomes more dilute and less acidic, causing the heavy metals to bind with the iron oxide and precipitate out of the water and settle into river bottom sediments.

What were the dilution factors?

At Animas River at Durango (USGS 09361500), the flow was 713 cfs (or 1414 acre-feet/day) on August 5, 2015 and 9.3 acre-feet of toxic spill resulted in an approximately 1:100 dilution. At San Juan River at Four Corners (USGS 09371010), the flow was 2,610 cfs (5,177 acre-feet/day) and the dilution is roughly 1:1000. At the Colorado River at Lee's Ferry, AZ (USGS 09380000), the Colorado River flows on average at between 13.5 and 14.7 million acre feet per year (Graf, 1997). So, 9 acre-feet of toxic spill over 13.5 million acre-feet per year is roughly 1 millionth of the flow for one year. In terms of the sediment load, the impacted sediment entering the Colorado River is roughly 190 tons and approximately, 44,400,000 tons of sediment arrives at Glen Canyon

Dam each year (Andrews, 1990; Weisheit, 2003). If all the sediment were to reach Glen Canyon Dam (excluding the existing sediment), the dilution is approximately 1:2,300,000.

Can the spill affect me or my family?

In general, short-term exposure to very high doses of metals such as lead, arsenic, mercury, cadmium, beryllium and chromium can cause poisoning. In the case of this spill, high levels of exposure could have only occurred at the mouth of the spill. But as it moves down the river, the plume is diluted and will stretch out and mix with local water and sediment that have higher pH. As the pH of the water rises, many remaining soluble metals will become insoluble and fall to the sediment bed mixing with the local sediment. At this point in time, we do not have adequate information to know what the long-term exposure levels will be north of Lake Powell or if these exposures will be different from exposure levels before the spill. Very long-term exposure to lower doses of these metals can cause damage to organs, particularly developing organs in children, and/or lead to illnesses like cancer. It will take time to determine if these levels of exposure will be high-enough to cause long-term effects on health. The chances of significant exposure to these metals directly resulting from the spill in the lower Colorado region are negligible.

What are the impacts at Gold King Mine or its immediate area?

The greatest risk exists at the Gold King Mine Site where the metals are in the highest concentration (Table 1). With a pH less than 5, the fish would die. Even at low concentrations, heavy metals (such as lead, copper and arsenic) are toxic to aquatic flora and fauna (Mohan et al., 2007).

What are the impacts in the Animas River and San Juan River confluence?

We will not know the extent of the long-term impacts of this highly concentrated release of metals into our environment for quite some time. See Puls, 1988 and Mukhtar, S. 1998 for more information on maximum contaminant levels for drinking water quality, in human, livestock and poultry. Even as the water in the river returns to normal levels through dilution and settling into the river bed sediments, there will still be potential for exposure. For example, the metals could bioaccumulate in fish that live in the river that feed on things that grow in the sediments. The contaminants could seep into the groundwater, resulting in impacts to drinking and irrigation water. If the metals deposit on river shores or in sediments they could ultimately dry out and become resuspended via wind. These resuspended particulates could contaminate surrounding soil, and they could also be inhaled. It will take time to determine if levels of contamination in the environment are high enough to result human health risks or affect flora and fauna over the long term.

What are the impacts at the San Juan River and Colorado River Confluence?

Once water and sediments from the Animas River enter the San Juan River, they are diluted and mixed in with many times the volumes water and tons of sediments that this river carries daily down to the Colorado. Therefore, it is highly unlikely that the overall water quality of the San Juan or the Colorado rivers have been or will be measurably affected by this release.

What are the impacts to Yuma Farmers?

Four pounds of cadmium were released in this toxic spill (Table 1). Cadmium is a heavy metal that is of concern in some soils in the Yuma area because it can accumulate in some vegetables

and grains. Using Colorado River daily flow volumes of water and sediments, we estimated that cadmium levels in water will be non-detectable and several orders of magnitude below the drinking water standard of 5 μg/L (Table 3). This is assuming that all the cadmium stayed in solution and stayed concentrated in one day's worth of Colorado River water of 13,000 acre-feet/day. Even dividing this daily Colorado flow by 10 or 100 the mass of cadmium spilled near Silverton would not be detectable in Yuma by present day methods of analysis. A similar case can be made with the approximately 190 tons of sediments released into the Animas and subsequently into the San Juan, which are dwarfed the sediment load of 44,400,000 tons of sediment that arrives at Glen Canyon Dam each year (Myers, 1998; Andrews, 1990; Weisheit, 2003). This reservoir is an immense storage of sediments in itself and will buffer/dilute/bury/trap beyond detection any soluble cadmium and any sediment from the spill that make it there. Therefore, our conclusion, at least for now, is that the impact on irrigation water quality in Yuma of this particular event (not including any past history of metals releases from that area) is not and will not be measurable. Table 3 shows typical measured metal levels, the range and mean, in the Colorado River diverted at Imperial Dam into the All-American Canal, the Gila River, and the Yuma Project aqueduct and compares it to the EPA National Primary Water Standards.

Table 3. Metal concentrations in Colorado River water diverted at Imperial Dam prior to the spill. (Sanchez unpublished data)

Metal	Range (μg/L)*	Mean (μg/L)	Standard (μg/L)**
Lead(Pb)	nd-0.66	0.17	15
Cadmium(Cd)	nd-0.07	0.05	5
Arsenic(As)	1.7-4.1	3.1	10
Uranium(U)	1.2-5.2	3.6	30

nd = not detected

**National Primary Drinking Water Standards (USEPA)

How can I sample water and sediment?

Since it is anticipated that most of the metals will be retained by sediments upstream of Glen Canyon Dam the impacts in the lower Colorado River regions should be negligible. Nevertheless, stakeholders are recommended to collect water samples for heavy metals analysis if they suspect that their water is contaminated. See this EPA protocol on water sampling for dissolved metals http://www.epa.gov/region6/qa/qadevtools/mod5_sops/surface_water_sampling/low_level_metals/r6wtr-sampling-metals.pdf and sediment sampling at http://www.epa.gov/region6/qa/qadevtools/mod5_sops/sediment_sampling/r9-sedimentsample_gui.pdf. Call 602-364-0728 for a list of certified labs. Reference background concentrations of metals in the Colorado River and the USEPA drinking water standards are provided at http://water.epa.gov/drink/contaminants/upload/mcl-2.pdf and more information on water quality standards related to livestock can be found in Puls, 1988 and Mukhtar, S. 1998. Public water utilities that use river water potentially impacted by this spill are monitoring and treating as needed to acceptable water quality standards. Contact your water provider if you have questions about the water quality at your tap. Please see Artiola et al. (2009) for home water treatment options and Uhlman et al. (2009) for drinking water well contaminants.

Basic Precautions When Using River Water

- Do not drink colored, murky water or with a distinct metallic/rust taste.

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- Water taken directly the river or from nearby shallow riverbed wells, should be filtered through fine particle filters (backpacking filters or commercially available in-line filter) to remove any suspended sediments from the water.
- In areas closer to the spill (Animas River) the pH of the water should also be checked; it should be at least above 6.5.
- Water used for animals, large and small, should be allowed to stand at least 24 hours to allow any sediment particles to settle out as much as possible.

Links

EPA updates on Gold King Mine http://www2.epa.gov/goldkingmine#updates
EPA Hotline 844-607-9700
Gold King Mine Incident Report http://epaosc.org/site/site_profile.aspx?site_id=11082
Water Quality Data http://epaosc.org/site/doc_list.aspx?site_id=11082

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